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# IMPLEMENTATION PACKAGE UDOT-IMP-76-1

# PIPE SELECTION FOR CORROSION RESISTANCE

UTAH DEPARTMENT OF TRANSPORTATION

RESEARCH & DEVELOPMENT UNIT

JANUARY 1977

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Prepared by

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January 1977

UTAH DEPARTMENT OF TRANSPORTATION
Materials and Research Section
Research and Development Unit

Prepared in Cooperation with the U.S. Department
of Transportation, Federal Highway Administration

TECHNICAL REPORT STANDARD TITLE PAGE

| | | |
|---|---|---|
| 1. REPORT NO.<br>UDOT-IMP-76-1 | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
| 4. TITLE AND SUBTITLE<br>PIPE SELECTION FOR CORROSION RESISTANCE | | 5. REPORT DATE<br>JANUARY 1977<br>6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S)<br>Joseph L. Leatham and Gordon E. Peterson | | 8. PERFORMING ORGANIZATION REPORT NO.<br>UDOT-IMP-76-1 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Utah Department of Transportation<br>Research and Development Unit<br>757 West Second South<br>Salt Lake City, Utah 84104 | | 10. WORK UNIT NO.<br>500-928<br>11. CONTRACT OR GRANT NO.<br>HPR-PL-PR-1(15) |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>Utah Department of Transportation<br>603 State Office Building<br>Salt Lake City, Utah 84114 | | 13. TYPE OF REPORT & PERIOD COVERED<br>Implementation Package<br>14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

Recommendations presented herein were adopted by the Standards Committee of the Utah Department of Transportation as of January 8, 1975.

16. ABSTRACT


Fifty-eight pipe culvert installations were evaluated for durability characteristics and assigned a Pipe Rating (PR) to aid in numerical analysis and correlation with environmental soil and water conditions.

Minimum soil resistivity is described as the most important single parameter affecting pipe culvert durability. Resistivity, however, is not reliable enough to use by itself to predict pipe corrosion. Minimum soil resistivity, pH, total soluble salts, and sulfate content are interdependent parameters affecting pipe corrosion.

Test procedures are given to facilitate determinations for minimum soil resistivity, pH, total soluble salts and sulfate content.

Total soluble salt content is a more significant factor than any single soluble salt content in predicting pipe material performance.

Selection guidelines are given along with examples to aid in pipe material selection.


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|---|---|
| 17. KEY WORDS<br>Pipe corrosion, pipe durability, pipe Rating, pipe selection | 18. DISTRIBUTION STATEMENT<br>No restrictions. This document is available to the public through the National Technical Information Service. Springfield, Virginia 22161 |

| | | | |
|---|---|---|---|
| 19. SECURITY CLASSIF. (of this report)<br>Unclassified | 20. SECURITY CLASSIF. (of this page)<br>Unclassified | 21. NO. OF PAGES<br>36 | 22. PRICE |

# SYNOPSIS

This implementation package describes the approach, procedures and selection criteria used by Utah to select durable pipe culvert materials. The package is directed towards obtaining the service demands of these pipe materials without incurring the expense of overdesign through inappropriate conservatism.

## THE PROBLEM

1) To better define and identify environmental soil parameters that significantly affect underground material corrosion and their relative quantative effects.
2) To provide standardized testing procedures for determining significant environmental soil parameters affecting corrosion.
3) To provide selection criteria based on soil parameters whose effects can be identified and quantified.

## THE SOLUTION

Development of observation techniques, testing procedures and selection guidelines to aid the materials and hydraulics engineers in selecting appropriate pipe culvert materials.

## THE BENEFITS

1) Reduces costs for pipe culvert materials by avoiding inappropriately conservative selection.
2) Provides a basis for selection supported by observations and testing to identify existing field conditions and significant corrosive soil constituents.
3) Outlines a procedure for estimating the extent and time for repair or replacement.

ACKNOWLEDGMENT

This material is based on a research report Pipe Corrosion and Protective Coatings by Bob H. Welch, Utah Department of Transportation formerly Utah Department of Highways, November 1974. It further incorporates background information from several previously published works.

TABLE OF CONTENTS

LIST OF FIGURES

# INTRODUCTION

## THE PURPOSE

The purpose of this implementation package is to provide an updated approach to the selection of pipe culvert materials. In the past a conservative approach has been taken because critical environmental parameters causing underground material corrosion were not adequately identified or quantified. The material presented in this package is directed towards obtaining the required service of pipe culvert materials without incurring the expenses associated with over design through inappropriate conservatism.

## BACKGROUND

Experience now indicates that certain environmental parameters of the culvert backfill soil and runoff waters influcence the expected corrosion performance or durability of various pipe materials and coatings. Abrasion has also been shown to be an important factor relating to the durability of pipe culverts.

Durability is the most important factor that must be considered in selecting a specific type of culvert pipe material for a given set of environmental conditions. Durability certainly influences the expected service life of a pipe culvert and should form the basis for selection of a particular pipe material as well as the thickness of the material or the protective coating that should be applied.

The information in this package is intended as a guide or supplement to enchance the experience and judgement of materials and hydraulics engineers when specifying pipe culvert materials.

Experience with existing pipes in any particular area as well as judgement as to the conditions existing there should be considered in conjunction with the graphs, test procedures and selection guidelines presented here.

The graphs, test procedures, and selection guidelines presented in this package were developed during the course of a research project conducted by the Utah Department of Transportation entitled "Pipe Corrosion and Protective Coatings" (Bob H. Welch - 1974).

# DEVELOPMENT

## IDENTIFICATION

The environmental parameters effecting durability had to be identified and quantified in order to bring about the development of appropriate selection criteria. To accomplish this a random selection of pipe culvert materials for corrosion and abrasion analysis were chosen to include a variety of pipe materials, environmental surroundings, and a wide span of time in place. Pipe with incomplete history of placement or specifications were excluded from evaluation.

Pipe materials that were evaluated included those that could be included under one of six categories as follows:

1) Reinforced concrete
2) Corrugated steel
3) Aluminum alloy
4) Bituminous coated corrugated steel
5) Bituminous coated asbestos bonded corrugated steel and,
6) Structural plate corrugated steel.

Specific pipe classes that fit under these categories are listed in Appendix A.

## INSPECTION

An inspection team was assigned to inspect and record observations at each of the pipe locations chosen for evaluation.

The actual on-site inspection procedures called for a variety of observations by the inspection team. On-site inspection and observations were recorded on a Test Site Evaluation Form as in Figure 1.

## TEST SITE EVALUATION FORM

Pipe No. 23-A District 6 Year Placed 1950

Pipe Location: 3.2 Miles West of Myton, Utah on U.S. 40.

Pipe Description Asbestos Bonded Bituminous Coated Corrugated Steel.

Pipe Coating Asbestos Bonded Bituminous Coated.

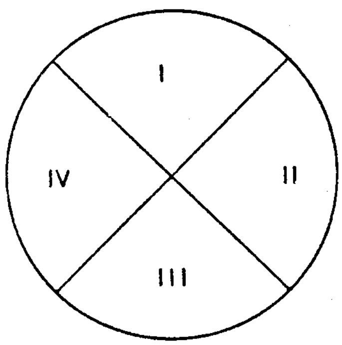
Pipe Size. . . . . . . 36" x Circular

In Place Thickness 86 mills Design Gauge 16

89 mills

91 mills

87 mills




| | Corrosion | Abrasion |
|---|---|---|
| I | Soil Side=5% | none |
| II | Both Sides<2% | none |
| III | Both Sides=8% | none |
| IV | Both Sides=5% | none |

Remarks: Coating approximately 10-15% intact. Corrosion begining on soil side of pipe. (see pictures). Invert looks good. Discoloration on approximately 40% of exterior side of pipe.

Picture Identification: 23A-Inlet Drainage Basin; 23B-Outlet Drainage Basin; 23C-Pipe Invert at 15ft in.; 23D-Section II Soil Side.

Type Drainage Basin: Semi-Arid Desert flat topography at <2% slopes

Slope of Drainage Basin

Soil

| | SOIL Field | SOIL Lab | | WATER Field | WATER Lab |
|---|---|---|---|---|---|
| pH | 9.3 | 9.6 | pH | | |
| Resistivity | NA | 400 ohm-cm | Resistivity | | |
| Soluble Salts | 3.4 percent | | Soluble Salts | (No flowing water) | |

Figure 1 TEST SITE EVALUATION FORM

Information was recorded for the following items:

1) Pipe location
2) Year placed
3) Pipe description
4) Pipe coating (bituminous, bituminous-asbestos bonded)
5) Pipe size (diameter in inches)
6) Pipe thickness
7) Design thickness (nominal gauge)
8) Location of corrosion (quadrants I through IV) See Figure 1
9) Degree of corrosion (in percent)
10) Degree of abrasion (in percent)
11) Pipe environment (remarks-height of fill etc.---)
12) Photographic identification (photo log number)
13) Type and slope of drainage basin
14) Soil and water conditions (pH, resistivity and soluble salts)

After the above inspection was accomplished, a 10.2-centimetre (4-inch) core (Figure 2) was cored out of each pipe inspected.

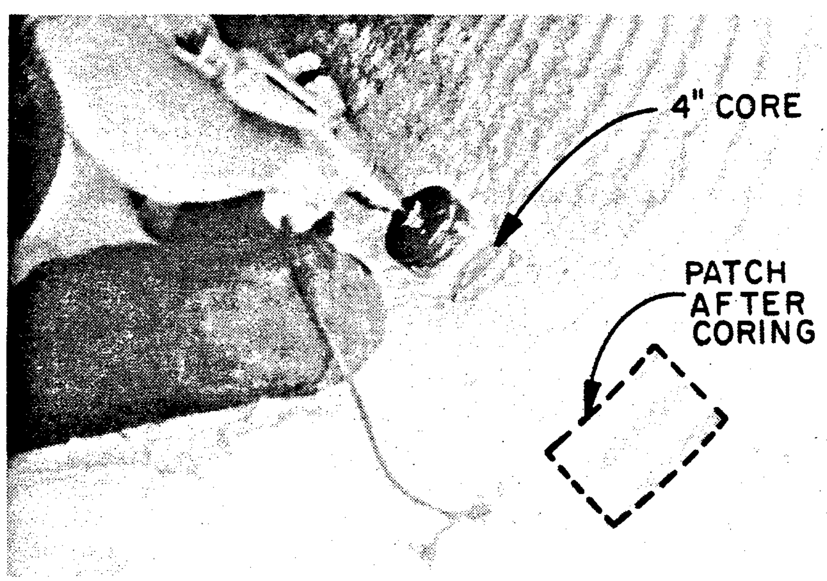



Figure 2 METAL CORE SAMPLE REMOVAL

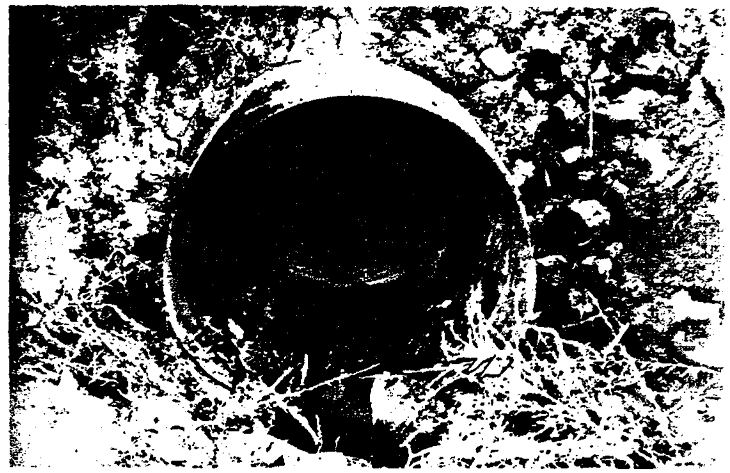
## TESTING AND RATING

At the laboratory the cores were first cleaned of any loose debris, visually evaluated, and assigned a tentative Pipe Rating (PR) on a scale ranging from 10 (excellent) to 0 (failure). Each core was then randomly measured in five locations for thickness to the nearest 0.025-millimetre (0.001-inch) and weighed with the average of the five thickness measurements being used as the thickness number. The samples were then stripped of their zinc coatings and again thickness and weight determinations were made. The tentative pipe rating evaluations were reviewed as a result of visual observations on each of the samples "core metal" condition. Final Pipe Ratings were assigned to the specimens from each location after field notes, photographs, and observations of the four inch cores from each pipe were completed. This PR became the final number designating the relative degree of corrosion for each pipe and formed the basis for numerical analysis. A PR of two (2) depicted a pipe that needed maintenance or replacement (not necessarily structural or hydraulic failure). Consequently, two (2) was set as a constant in the equations developed to solve for age. Since the corrosion process itself may not be linear with respect to time, the age scale was adjusted by a factor so that the equation would adequately describe the correlation between a pipe rated at 2 and the age required to attain the condition where PR = 2. From these equations a constant adjustment was made for various types of coatings and metal thicknesses. Typical Pipe Ratings and associated environmental conditions are illustrated in Figures 3 and 4.

## ANALYSIS

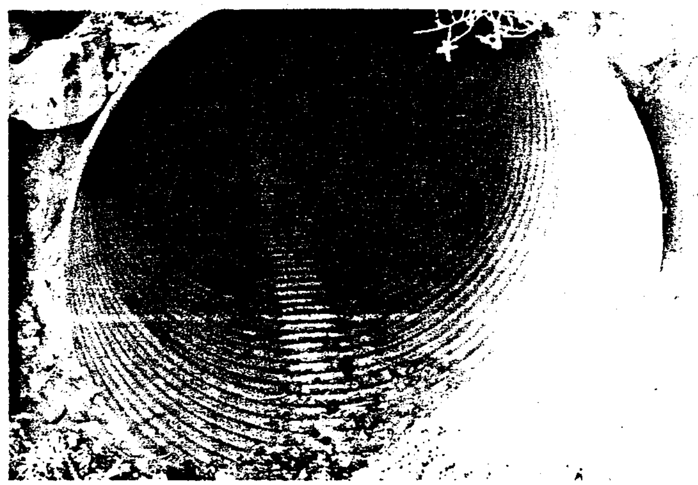
The statistical and numerical analyses of data obtained from the soil

33 year old bituminous coated corrugated steel pipe
pipe PR = 2 pH = 8.5 R = 150
coating PR = 1 SS = 4.5

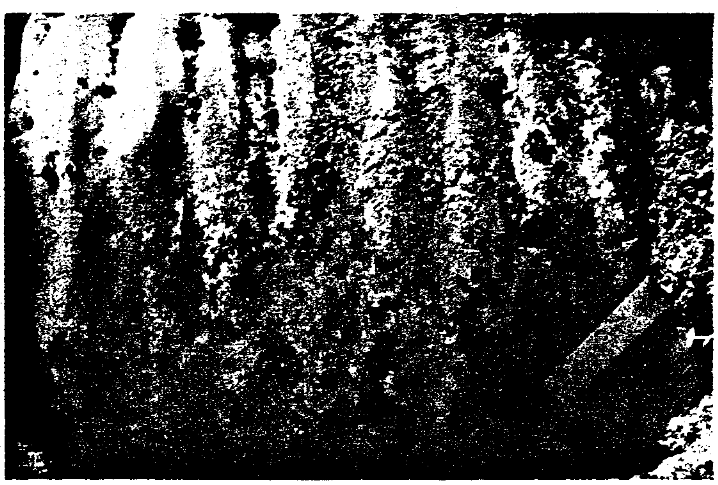


33 year old bituminous coated corrugated steel pipe
pipe PR = 2 pH = 8.5 R = 150
coating PR = 1 SS = 4.5

18 year old plain corrugated steel pipe
pipe PR = 3 SS = 1.2
pH = 8.3 R = 2000



14 year old plain corrugated steel pipe
pipe PR = 9 SS = 0.8
pH = 8.2 R = 2800



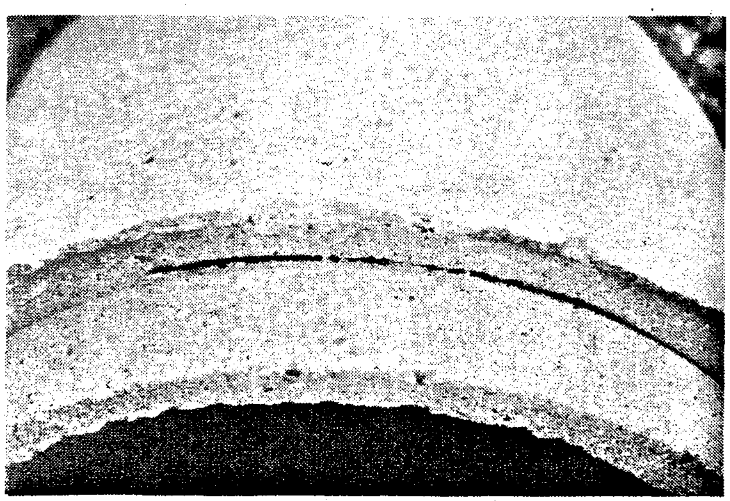
16 year old Bituminous coated corrugated steel pipe
coating PR = 2 pH = 7.6 R = 1100
pipe PR = 3 SS = 5.2

Close up of a 19 year old asbestos bonded, bituminous coated corrugated steel pipe
coating PR = 4 pH = 8.5 R = 1300
pipe PR = 7 SS = 1.1

and water samples were categorized in three main areas. First a simple correlation coefficient matrix was determined using all variables from all samples for possible correlation or dependency of any one environmental parameter with another. Secondly, this procedure was duplicated by isolating the data for each type of culvert material with a water analysis;

23 year old reinforced concrete pipe
Pipe PR = 3 SS = 1.2
pH = 7.9 R = 325

23 year old reinforced concrete pipe
Pipe PR = 3 SS = 1.2
pH = 7.9 R = 325



31 year old reinforced concrete pipe
Pipe PR = 7 SS = 0.8
pH = 8.0 R = 1200

Figure 4 TYPICAL PIPES IN CLASS F

comparing without a water analysis; running comparisons with both a water and soil analysis; and with combinations of like materials such as corrugated steel and bituminous coated corrugated steel pipes. The results from this analysis provided a guide as to how various combinations of these single independent parameters could be formed for potentially better correlations. The third area included the resultant groups of data that were then analyzed for multiple correlation coefficients.

Additional soil samples were taken from the soil side of the culvert for analysis in the laboratory at a later date. Where runoff waters were discharging through the culvert, a corresponding water sample was also obtained.

The soil samples obtained from around each drainage structure were analyzed in the laboratory for physical and chemical characteristics as follows:

1) Percent natural moisture
2) Total soluble salts
3) Soil pH
4) Silicon dioxide
5) Iron oxide
6) Aluminum oxide
7) Calcium oxide
8) Magnesium oxide
9) Soluble sodium oxide
10) Insoluble sodium oxide
11) Soluble potassium oxide
12) Insoluble potassium oxide
13) Chlorine
14) Carbon dioxide

15) Sulfates, and

16) Organics

Soil samples received from drainage structures having a flow of water were also tested for minimum resistivity using the field water in lieu of distilled water. Water samples where available were analyzed for the following:

1) Sulfate (ppm)

2) Chlorine (ppm)

3) Calcium oxide (ppm)

4) Magnesium oxide (ppm)

5) Sodium oxide (ppm)

6) Potassium oxide (ppm) and

7) Carbon dioxide (ppm)

All laboratory analyses were conducted at the same location by the same personnel.

## FINDINGS

### DESIGN LIFE

Findings presented in this section are directed primarily towards determining the useful design life of underground culvert materials. These findings may also be applicable to similar underground installations such as storm drains, cross drains, side drains or bin walls as shown in Figure 5 when exposed to underground, long term deterioration by the immediate soil environment.

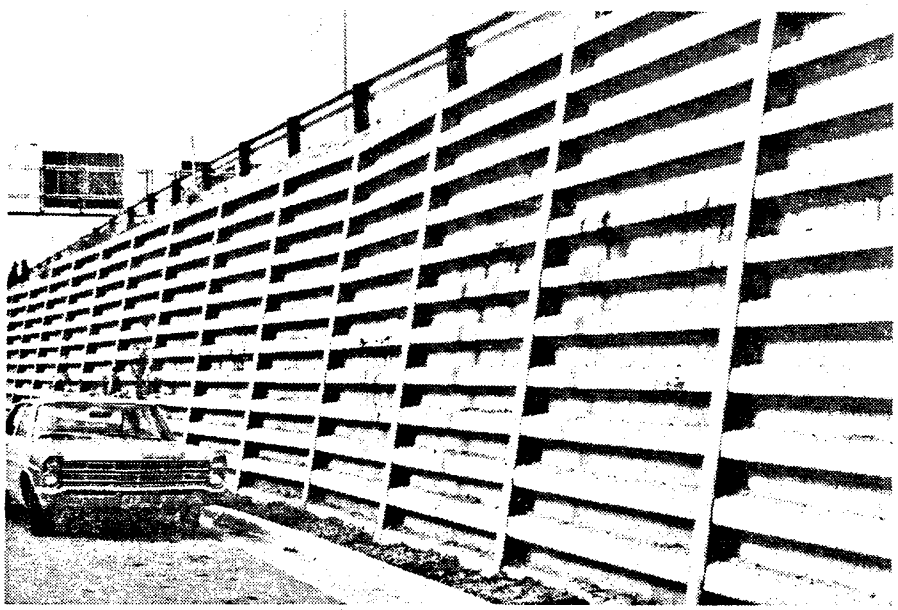


Figure 5 BINWALL EXPOSED TO CORROSIVE ACTION OF SOIL

Inspection of culvert pipes indicated that the durability criteria of corrosion and abrasion should be given adequate consideration during the design and planning phases of highway development in conjunction with structural, hydraulic, construction, material availability, and economic considerations.

During the course of the pipe evaluation, it became apparent that there were no acidic (pH$<$7) soils in Utah. All soil pH's examined were in the alkaline range.

CORROSION

Observations regarding pipe corrosion and durability as a result of investigating several pipe sites showed that the pipe extremities (outer six to eight feet) corrode at a much faster rate than the interior of the pipe. All areas around the exterior circumference of the pipe corroded at approximately the same rate. The predominant area where corrosion appeared to be a problem was on the exterior or soil side of the pipe and not on the invert side. Figure 6 shows this condition.

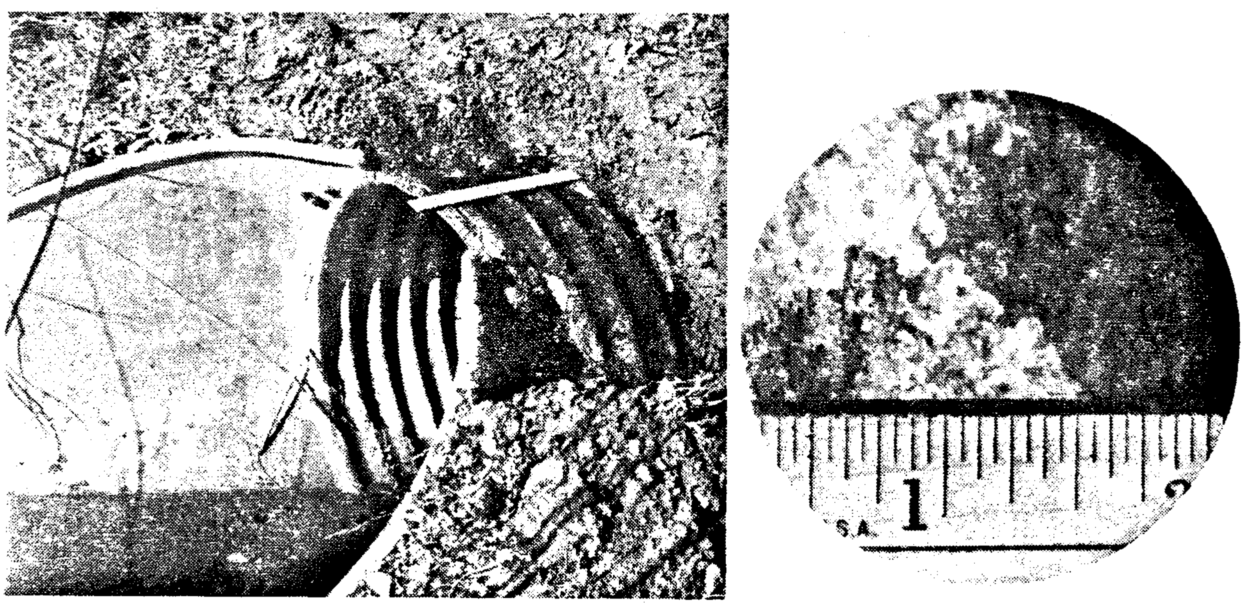


Figure 6 PIPE EXTREMITY SHOWING CORROSION ON THE EXTERIOR SURFACE

ABRASION

In general, due to the predominantly flat topography and basically arid or semiarid climates at the sites examined and because there were only six locations that had a continuous year round water flow, abrasion and scouring did not seem to be a problem for most pipe installations. Sediment buildup was a more serious problem than scour or invert abrasion. Abrasion will occur in unprotected aluminum alloy pipes if the mean annual flow carries a bedload of abrasive material at a velocity of 2.1 metres (7 feet) per second or more.

## SPECIFIC RESULTS

Specific results developed through the statistical analysis of the data obtained from the soil and water around each pipe location include a simple correlation matrix for each class of pipe and all pipe classes together. Simple correlation coefficients for each class of pipe using the more widely accepted independent variables of age, minimum soil resistivity, soil pH, total soluble salts, and the natural moisture content versus certain combinations of dependent variables such as Pipe Rating (PR) Highest Pipe Rating (HPR), Lowest Pipe Rating (LPR), Metal Loss (ML), and HPR-LPR were summarized.

From this analysis it was determined that the most important parameter if used by itself to describe pipe performance was the minimum soil resistivity (R).

Figure 7 shows the plot of pipe ratings versus resistivity, and even through resistivity may be the single most important variable; it is felt that because of the widely scattered data that using this single variable is not reliable enough to explain pipe corrosion.

Using multiple linear regression analysis and combining variables, two equations were selected as the most suitable to represent the respective interaction of the environmental parameters effecting pipe performance. The concrete pipe equation is as follows:

$$\log PR = 0.66 + 0.18 \log \left(\frac{R}{SS \times pH \times Age}\right) \qquad (1)$$

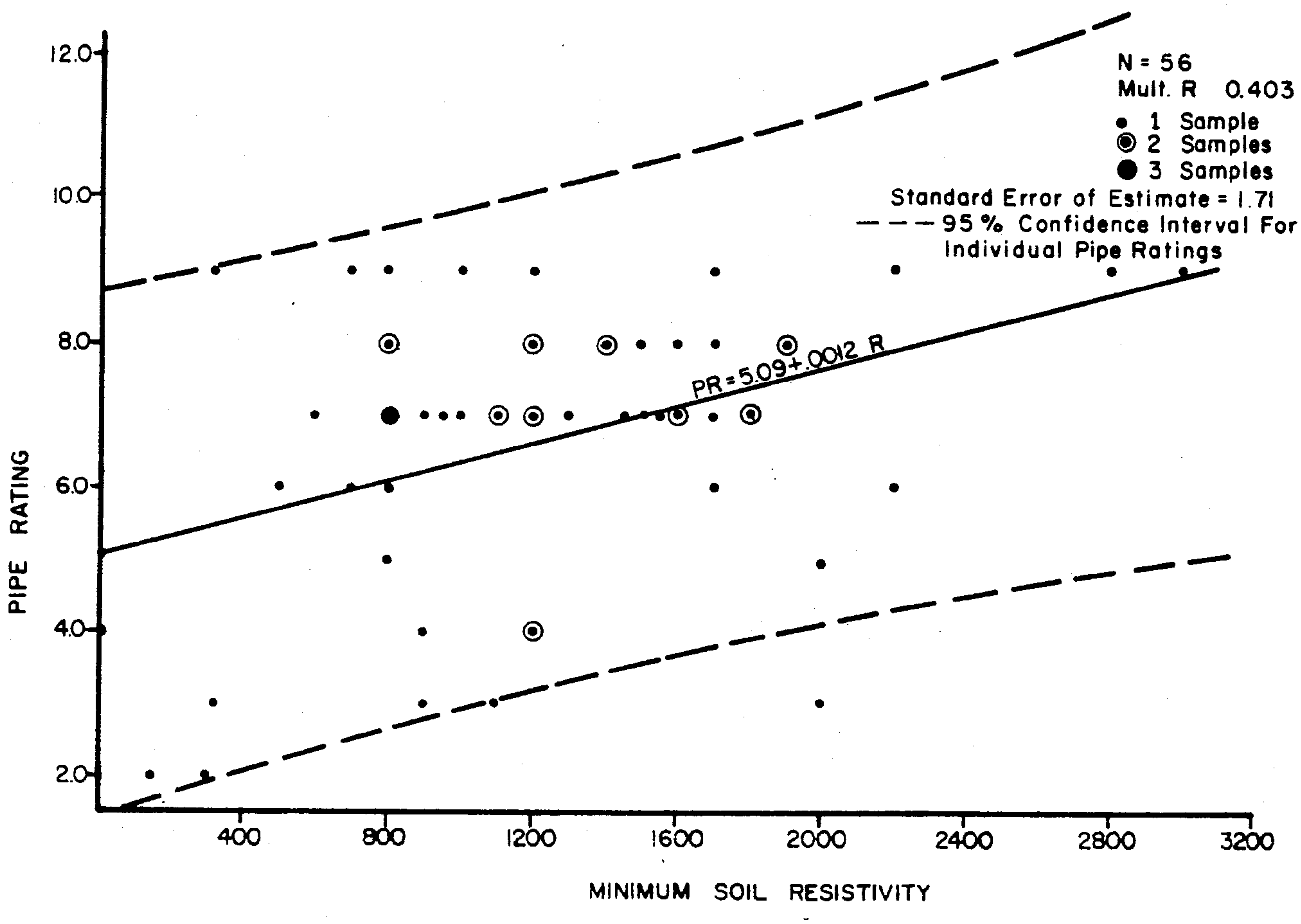



Figure 7 PR VS. MINIMUM SOIL RESISTIVITY

where PR = Pipe rating

R = Minimum soil resistivity

SS = Total soluble salts

pH = Range between acidic and basic

Age = Number of years in place

and the equation for plain corrugated steel pipe is:

$$PR = 9.25 + 0.15\ SS + 0.007\left[\left(\frac{R}{SS \times pH}\right)\right] - 0.0013 \times SS \times pH \times Age - .06pH^2 \qquad (2)$$

There is insufficient data at this time to derive a significant relationship between these environmental parameters and the years to failure for any of the pipe categories except for plain corrugated steel pipe and reinforced pipes.

Figure 8 represents the portland cement concrete pipe, type - II cement using equation (1). It should be noted that Figure 8 for concrete pipe works well for Utah's alkaline soils with the exception of three pipe locations. The three respective soil conditions at these locations contain sulfate content of 0.5 percent or higher. Therefore in soils containing sulfates in excess of 0.5 percent, type V cement is recommended.

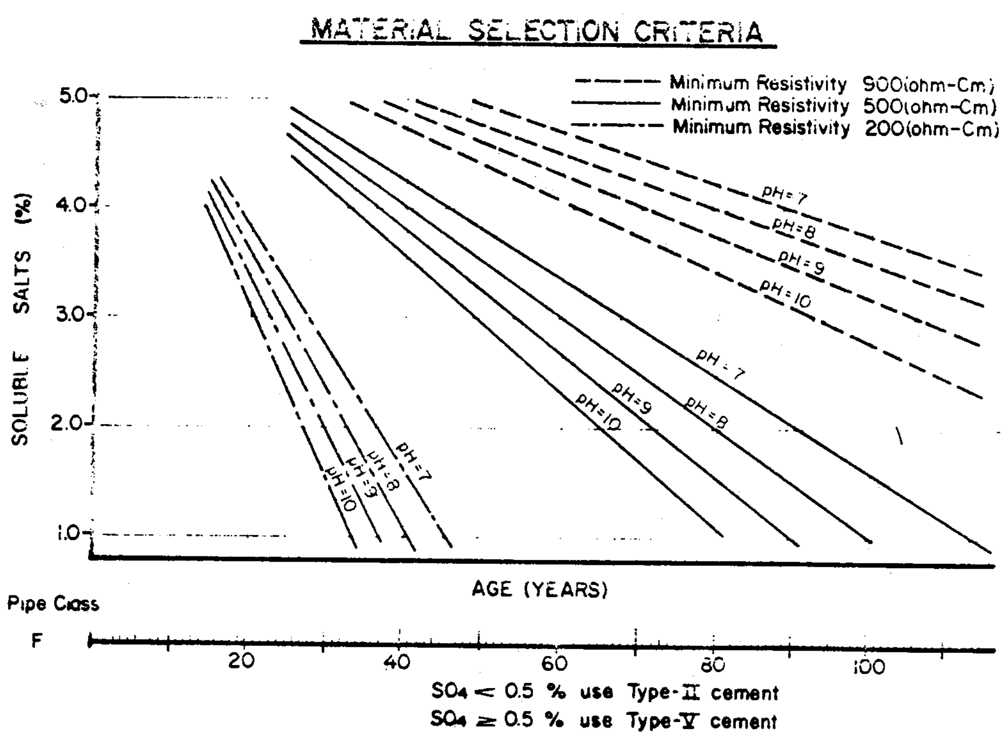



Figure 8 MATERIAL SELECTION CHART FOR CONCRETE PIPE

Figure 9 represents the plain corrugated steel pipe using equation (2).

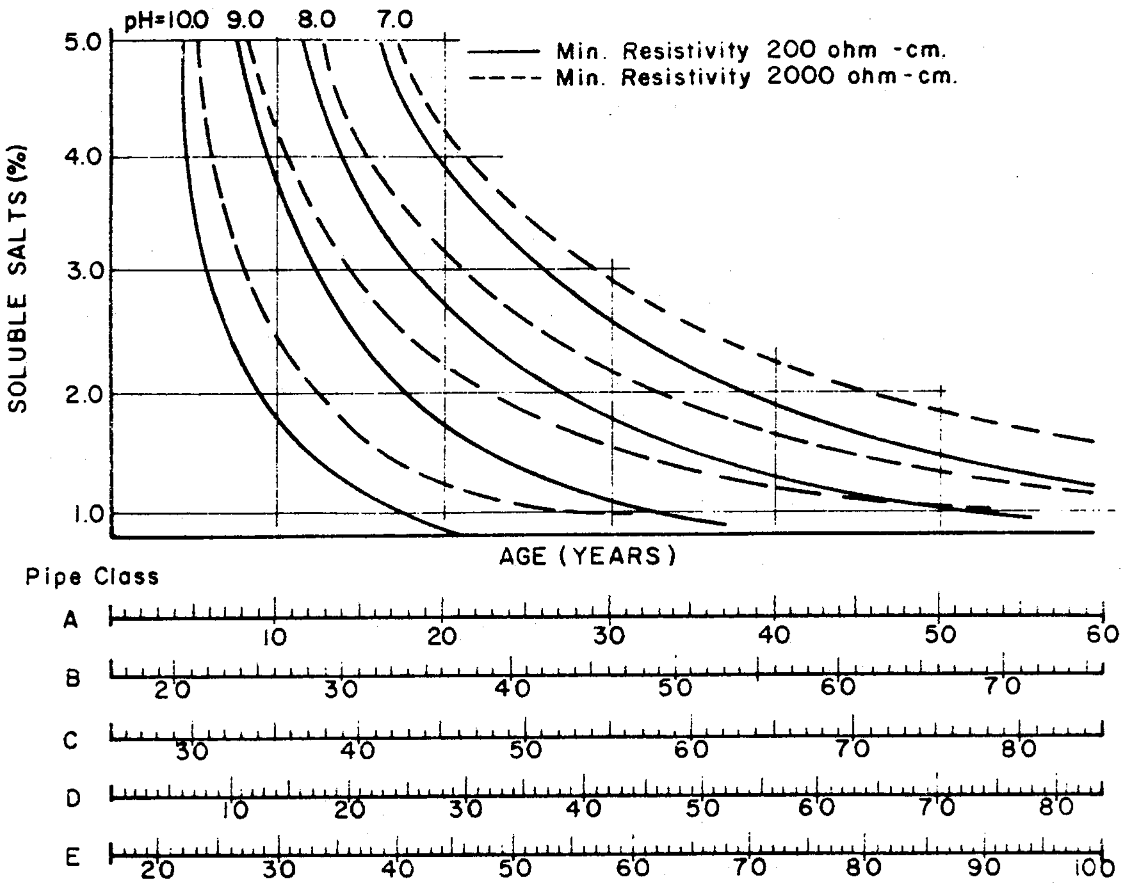



Figure 9 MATERIAL SELECTION CHART FOR PIPE CLASSES A THROUGH E

# SELECTION GUIDELINES

## OBSERVATIONS

During the preconstruction phases of highway design existing pipe culvert installations should be examined. The condition of these pipes if they are located in the same vicinity as the proposed pipes can be indicative of the enviromental conditions to which the new pipes will be exposed.

These selection guidelines constitute a guide for estimating the service life that can be expected to be achieved by various pipe materials. The guide values should be considered along with actual service lives of comparable existing materials in the same area.

## SAMPLING

Thorough sampling of the soils and water in the immediate vicinity of proposed pipe installations is necessary so that adequate testing can be conducted.

An effective sampling technique includes obtaining approximately 4.5 kilograms (10 pounds) of soil for each sample in all the natural drainage locations such as gulleys, valley bottoms, natural waterways and the like. Individual samples should not be taken from surface soils, but would best be obtained from approximately 15.6 centimetres (6 inches) beneath the soil surface. Samples should be obtained at that depth to avoid contamination from deicing chemicals, fertilizers and the like. In embankment cut areas where drainage structures are likely to be located, a soil sample at that elevation beneath the soil surface is most desirable. Soil samples from areas where imported fill material is to be taken, if known, should also be included.

Where present, water samples should be taken along with soil samples and tested for soluble salt content and pH.

## TESTING

Soil samples should be tested for minimum soil resistivity, soil pH, total soluble salts and soil sulfate content. Test procedures for determining these characteristics are contained in Appendix C. These test procedures are recommended for use in determing the soil properties because the charts and suggestions contained in this package were developed using these procedures.

## SELECTING THE MATERIAL

When the observations, sampling, and testing are completed the pipe culvert material can be selected through the use of the Material Selectrion Criteria Charts (Figures B-1 and B-2) in Appendix B.

Examples in Appendix B are given showing selection technique for eliminating pipe classes that would not meet minimum life expectancy values. Several pipe classes listed in Appendix A may meet the minimum life expectancy. In cases where several pipe classes meet the requirements; selection of the actual pipe culvert material reverts back to judgement, economics and material availability.

When the pipe selection charts indicate no culvert material type will yield the required service life in the natural soil conditions, an imported backfill with less harsh corrosive agents should be used.

Recommended abrasion limits for use of any pipe material without a paved invert is 2.1 meters per second (7.0 fps) as determined by the mean annual flow, or any flow which will carry up to a mean abrasive bedload of 7.6 centimeters (3 inch) diameter rocks. If the mean average annual flow is above 2.1 metres per second (7.0 fps) and/or will carry a mean abrasive bedload of 7.6 centimetres (3-inch) diameter rocks or larger, only pipe materials or pipe materials with coatings not susceptable to such structural attack should be specified. This would include the culvert materials in pipe classes A, D, or F.

PRECAUTIONS

It was found that the soil conditions, particularly soluble salts, pH and minimum resistivity vary too much from one location to another to adequately implement the use of USDA iso maps without a large error in proper pipe material selection. The USDA maps where the scale is 2.5 cm-60 m (1"-200') are not accurate enough for proper use. Therefore, in the pre-construction phases of highway design, the materials engineer should sample soils in pipe culvert locations to identify potential corrosion areas. However, to provide a good indicator of the soil conditions in the corresponding drainage basin, the use of iso maps could be very helpful.

Extreme care should be exercised when extrapolating the findings of this package beyond the limits from which they were developed, or where extreme soil or water conditions exist that are not accounted for in these selection criteria. A list of soil or water runoff conditions where results determined from these selection criteria may not correlate with field experience is as follows:

- Minimum soil resistivity less than 150 ohm-cm
- Soil pH less than 7.0 or greater than 9.6
- Soluble salts greater than 10 percent or less than 0.8 percent
- Sulfate content greater than 0.5 percent
- Continuous flows with an abrasive bedload

A minimum of 0.8 percent total soluble salts should be used at all potential pipe locations, since after 20 years of service most roadside soils will accumulate this soluble salt content.

Wherever the sulfate content exceeds 0.5 percent and concrete pipes are used, the cement should be specified as Type-V. The life expectancies as shown on Figure B-2 remain the same for Type-V cement with sulfates greater than 0.5 percent as for Type II cement when sulfates are non-existant to 0.5 percent.

It should be noted that, due to the predominantly alkaline soils examined, if the organic content is one (1) percent or higher the constraints imposed by pH may be somewhat conservative. The total extent to which these constraints may be relaxed are not quantified but must be the opinion of the materials engineer responsible for pipe material selection.

Aluminum alloy pipe and alluminum alloy structural plate pipe shall not be used when the mean annual flow can be expected to carry a bedload of abrasive material at a velocity of seven feet per second or more. Under such condition, a concrete invert shall be used in all steel structural plate pipe and in all steel pipe 150 centimeters (60 inches) or more in diameter. Aluminum must be asphalt coated to prevent direct contact with fresh concrete used to construct catch basins, cleanout boxes or headwalls.

When steel and aluminum elements are jointed, the two metals must be insulated from direct contact with each other by an approved method. When existing culverts are extended, the extentions shall be of the same material.

# APPENDIX A

# PIPE CLASSES

## Categories in Pipe Class

The "pipe class" categories as indicated on the pipe selection charts refer to a pipe material or groups of materials as indicated below:

| PIPE CLASS | MATERIAL |
|---|---|
| A | Plain Corrugated Steel. |
| B | Bituminous Coated Corrugated Steel Pipe. |
| | Aluminum Alloy Pipe |
| | Pitch-Resin Adhesive Coated Corrugated Steel Pipe, (coated on exterior side only). |
| C | Asbestos Bonded Bituminous Coated Corrugated Steel Pipe. |
| | Pitch-Resin Adhesive Coated Corrugated Steel Pipe, (coated on both sides) |
| D | Plain Corrugated Steel Structural Plate Pipe |
| E | Bituminous Coated Corrugated Steel Structural Plate Pipe |
| | Aluminum Alloy Structural Plate Pipe |
| F | Portland Cement Concrete Pipe Type-II Cement. ($SO_4$ 0.5 percent) |
| | Portland Cement Concrete Pipe Type-V Cement. ($SO_4$ 0.5 percent) |

Figure A-1 CATEGORIES IN PIPE CLASSES

# APPENDIX B

# MATERIAL SELECTION

Example No. 1

Soil Condition: pH = 8.5, R = 1700 ohm-cm., SS = 1.5%

Required Service Life = 40 years.

- Draw a line on Figure B-1 through the SS = 1.5%.
- Extrapolate 1700 ohm-cm between the R = 200 and R = 2000 lines on the pH = 8 and pH = 9 sets of curves.
- Since pH = 8.5, measure 1/2 the distance between the R = 1700 of pH = 8 and pH = 9 on the SS = 1.5% line.
- Extend this point vertically downward through the pipe class scales.
- Repeat the process on Figure B-2 (Resistivities are plotted as a family of curves and the pH's are labeled in each resistivity set).
- Results:

| | | |
|---|---|---|
| Pipe Class A = 36 years | 40 years | Not acceptable. |
| Pipe Class B = 52 years | 40 years | Acceptable. |
| Pipe Class C = 61 years | 40 years | Acceptable. |
| Pipe Class D = 50 years | 40 years | Acceptable. |
| Pipe Class E = 66 years | 40 years | Acceptable. |
| Pipe Class F = 200+ years | 40 years | Acceptable. |

Therefore, any pipe material with the exception of uncoated galvanized metal pipe will satisfy the required service life under the given set of environmental conditions.

NOTE:

Had the required service life been 30 years instead of 40 years, then all pipe classes would satisfy the requirements.

If the organic content of this soil would have been high (3%), then the border line pipe class of "A" would most likely satisfy the requirements.

If the sulfate content were high (0.5% or more) then judgement would

NOTE: (continued)

most likely favor only pipe class E to satisfy the requirements. Type-V cement should also be specified.

Had the soil conditions been severe enough that no pipe class would satisfy the service year requirements of 40 years, then a select backfill with higher R, lower SS or lower pH should be specified.

Example No. 2

Soil Condition: pH = 7.5, R = 1800, SS = 2.5% and S = 0.2.

Required Service Life = 40 years.

- Draw a line on Figure B-1 through the SS = 2.5%
- Extrapolate 1800 ohm-cm between the R = 200 and R = 2000 lines on the pH 7 and pH 8 set of curves.
- Since pH = 7.5, measure 1/2 the distance between the R = 1800 of pH = 7 and pH = 8 on the SS = 2.5% Line.
- Extend this point vertically downward through the pipe class scales.
- Results:

| | | |
|---|---|---|
| Pipe Class A = 29 years | 40 years | Not acceptable |
| Pipe Class B = 45 years | 40 years | Acceptable |
| Pipe Class C = 54 years | 40 years | Acceptable |
| Pipe Class D = 41 years | 40 years | Acceptable |
| Pipe Class E.= 57 years | 40 years | Acceptable |

NOTE: Both types of concrete pipe are acceptable because of the high resistivity value (1800).

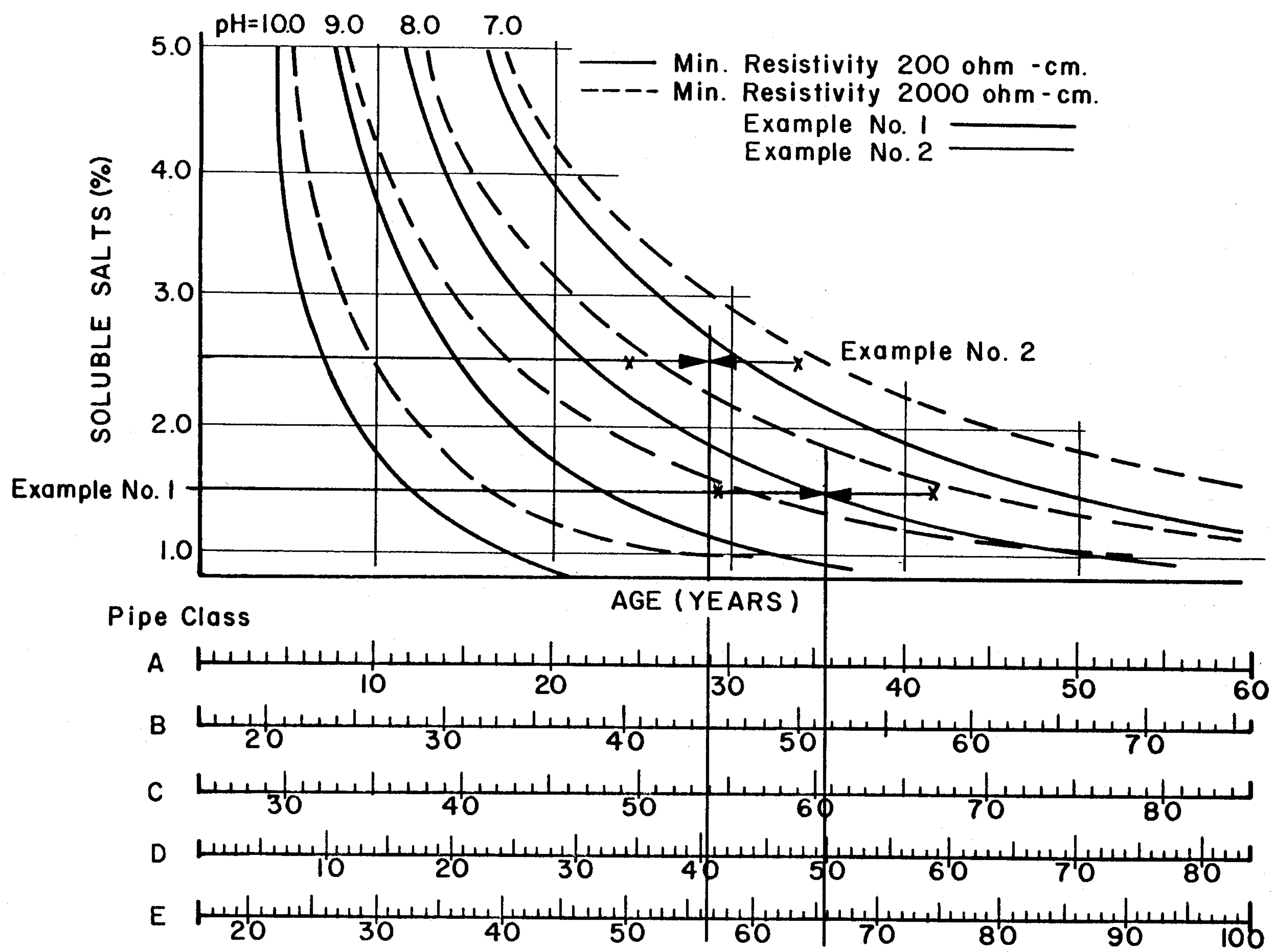



Figure B-1 MATERIAL SELECTION CRITERIA FOR PIPE CLASSES A THROUGH E

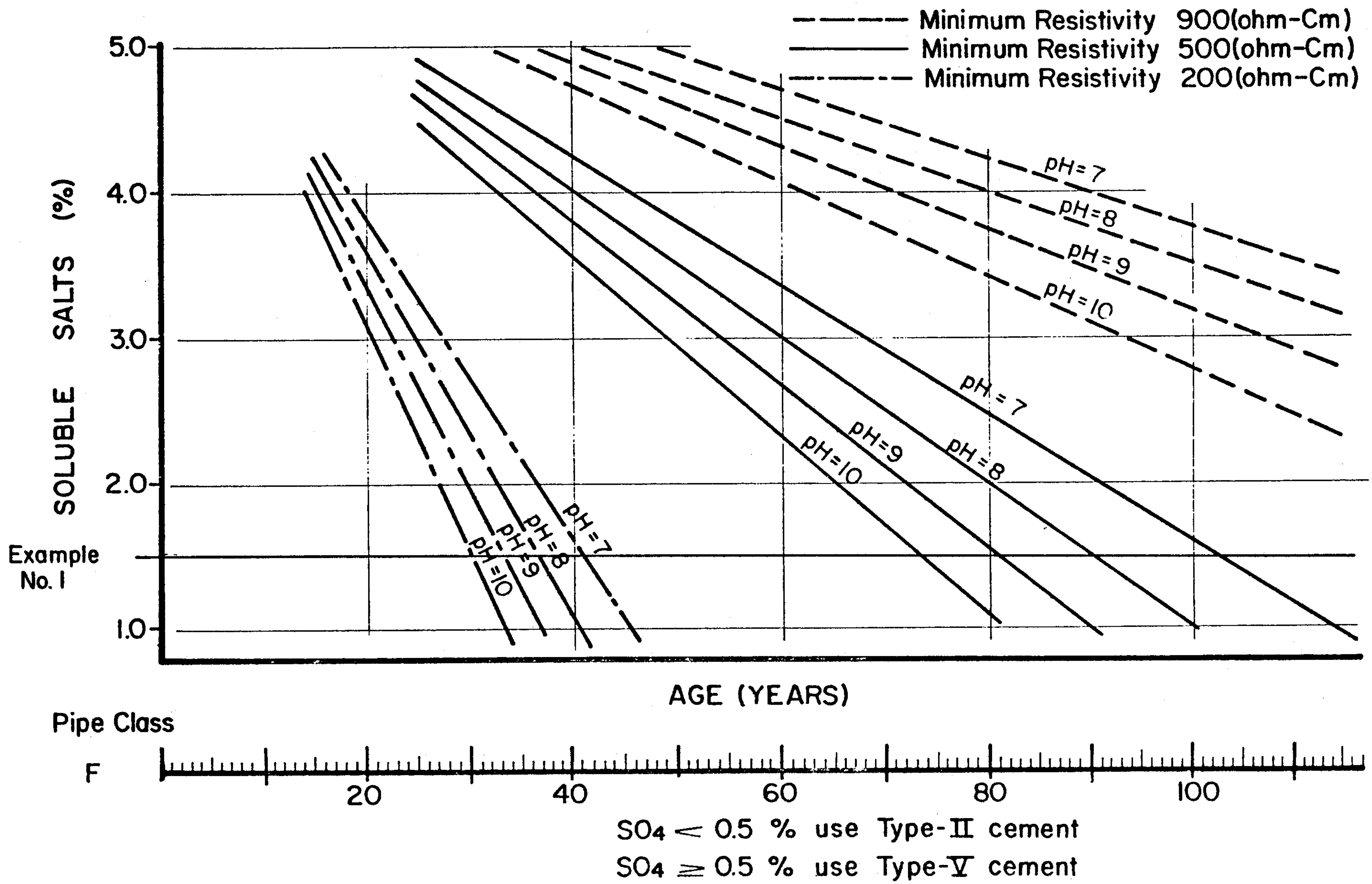



Figure B-2 MATERIAL SELECTION CRITERIA FOR PIPE CLASS F

# APPENDIX C

# TEST PROCEDURES

# 8-934 LABORATORY DETERMINATION OF pH FOR SOILS

## 8-934.01 Scope:

This method of test covers the procedure for determining the pH values of water samples and soil samples in the laboratory.

## 8-934.01 Apparatus and Materials:

1- Beaker - An approved 150 ml beaker.

2- Scoop or Teaspoon - A scoop or teaspoon measure having the capacity of 5 ml.

3- Washbottle - A plastic wash bottle suitable for use with distilled or demineralized water for adding water to samples and washing equipment.

4- pH Meter - A meter specifically designed to read directly the pH value of soil and/or water samples. The type containing a combination glass electrode is preferred.

5- pH Standard Solution - A solution to be used as a standard reference when testing for pH.

## 8-934.03 Procedure:

A. pH Determination of Water Samples:

(1) Following individual pH meter instructions for warm-up time and standardization with pH standard solution(s).

(2) Pour water in 150 ml beaker.

(3) Place the pH meter electrode in the beaker and allow the pH meter needle or digital readout indicator to stabilize.

B. pH Determination of Soil Sample:

(1) Same as Number 1 under part A of procedure above.

(2) Mix thoroughly a slurry of 20 millilitres of the soil sample and 20 millilitres of distilled or demineralized water in a 150 ml beaker.

(3) See Number 3 in part A of procedure above.

(4) Record the reading as the pH of the soil sample.

# 8-939 LABORATORY DETERMINATION OF THE RESISTIVITY VALUE OF SOIL

8-939.01 Scope:

This method of test covers the procedure for determining the resistivity values of water and soil samples.

<u>8-939.02 Apparatus and Materials:</u>

1) Resistivity Meter - An ohmmeter suitable for laboratory analysis.

2) Soil Box - A soil container calibrated for use with resistivity meter (See Fig. 8-939-1).

3) Sieve - An approved number 8 (2.38 mm) sieve.

4) Stainless Steel Bowls.

5) Balance - A balance with a 5Kg capacity and sensitive to 10 grams.

6) Distilled or demineralized water.

<u>8-939.03 Procedure:</u>

A. <u>Water Determination</u>:

1) Take precautions to insure that the stainless steel plates are clean and free from any film before evaluating a sample.

2) Stir water sample vigorously with clean glass stirring rod.

3) Pour water sample into a clean calibrated soil box to its maximum capacity.

4) Zero the soil resistivity meter by clamping the two terminals together.

5) Connect the leads from the resistivity meter to the two exposed terminals on the soil box.

6) Read the value obtained on the ohm scale of the resistivity meter and record.

B. <u>Soil Determination</u>:

1) Obtain a soil sample weighing approximately 1300 grams of the material passing the No. 8 (2.38 mm) sieve, by quartering or splitting.

2) Add sufficient amount of distilled or demineralized water to the 1300 grams of soil as previously obtained to bring soil to its approximate plastic limit, mixing thoroughly.

3) Compact the soil in the soil box. Compaction with hands and fingers is sufficient. Strike off excess soil with straight edge.

4) Connect the leads from the resistivity meter to the ends of the two exposed terminals on the soil box, read the resistivity value on the ohm scale of the resistivity meter, and record.

5) Remove the soil from the box, and add approximately 100 cc. of distilled or demineralized water to the soil sample and again thoroughly mix.

6) Place contents into the soil box, compact and again measure the resistivity.

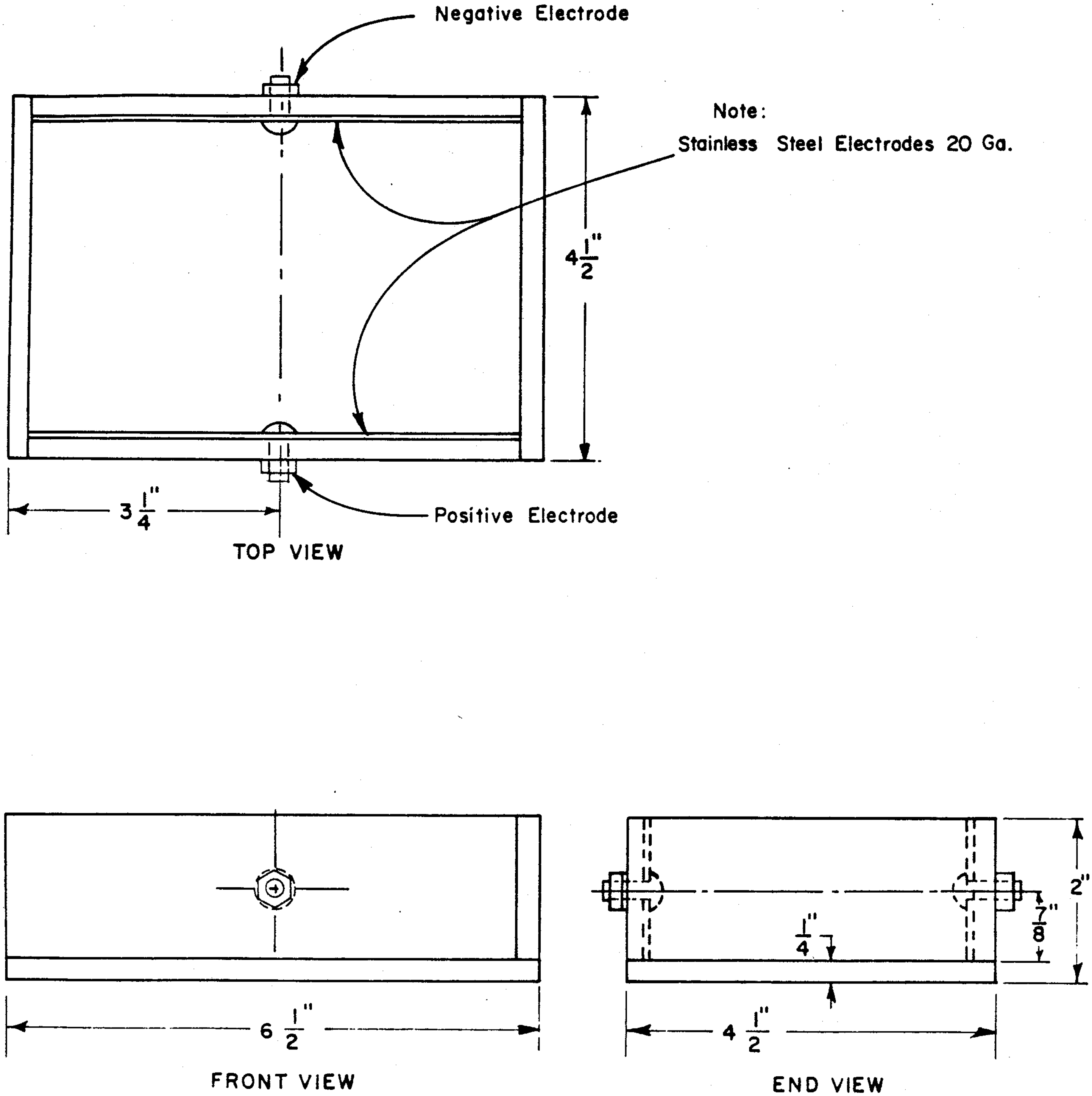
7) Repeat the procedure until a minimum value is obtained.

8) Record the minimum value as the resistivity of the soil.

8-939.04 Precautions:

1) Make sure meter leads are connected to corresponding soil box leads to read minimum resistivity.

2) Thoroughly clean all equipment that comes in direct contact with woil and/or water samples before and after testing.




Soil Box For Laboratory Resistivity Determination

Figure C-1

# DETERMINATION OF WATER SOLUBLE SULFATES IN SOIL

## SCOPE:

This method of test describes a procedure for determining the amount of water soluble sulfates in soil, including calcium sulfate.

## APPARATUS:

(1) Balance - accurate to within 0.0001 gram.

(2) Beakers - with watchglass covers, 400 ml

(3) Wash Bottle

(4) Filtering Funnel

(5) Glass stirring Rod to cover 400 ml beaker

(6) Filter Paper - retentive filter paper of an approved type. Such as Whatman No. 42 or S&S Blue Ribbon or equivalent.

(7) Platinum Crucible or Annealing Cup

(8) Hot Plate

(9) Muffle Furnace - an approved muffle furnace capable of attaining temperatures of between 800°C and 900°C

(10) Desicator

(11) Graduated Cylinders - 250 ml and 10 ml

## REAGENTS:

(1) Ammonium Chloride

(2) Barium Chloride

(3) Hydrochloric Acid

(4) Silver Nitrate

(5) Ammonium Hydroxide

(6) Methyl Red Indicator Solution

(7) Distilled Water - or demineralized water

PROCEDURE:

(1) Weigh out 1.000 gram of dry soil less large sulfate content is expected, place the soil in a 400 ml beaker.

(2) Add approximately 200 ml distilled water and 10 ml HCl

(3) Stir thoroughly and then boil the mixture for 5 minutes.

(4) Add $NH_4OH$ drop-wise until solution is alkaline. Use methyl red indicator to ensure alkalinity. (The alkaline solution filters faster and cleaner)

(5) Let precipitate settle then filter the hot mixture through a retentive filter paper and wash several times with hot distilled water. Acidify the filtrate with HCl. Add 10 ml 10% $BaCl_2$ solution. (If a large precipitate is immediately formed, the procedure should be repeated using a smaller sample + 3 grams $NH_4Cl$.)

(6) Warm filtrate and filter through retentive filter paper. Wash paper with hot distilled water until filtrate does not show any white precipitation when checked with silver nitrate solution. Usually 6 to 10 washings.

(7) Place the filter paper and contents into a tared crucible or annealing cup. Place in a furnace and slowly char, and consume the paper. Then ignite at 800 to 900° C.

(8) Cool in a desicator and weigh the $BaSO_4$ to the nearest 0.0001 gram.

(9) $$\text{Percent } SO_4 = \frac{(\text{grams } BaSO_4)(0.4115)}{\text{Sample weight}} \times 100$$

## SOLUBLE SALT DETERMINATION

SCOPE:

This method of test covers the procedure for determining the amount of water soluble salts in soil samples. Small amounts of salts that are considered insoluble, such as calcium carbonate, will be unavoidably included since they are slightly soluble. Water of crystallization is ignored.

APPARATUS AND MATERIALS:

(1) Balance - accurate to 0.001 gram.

(2) Beakers - 250 ml and 400 ml.

(3) Hot Plate - an approved hot plate.

(4) Graduated Cylinder - an approved 250 ml graduated cylinder.

(5) Watchglass - an approved watchglass suitable for covering a 400 ml beaker.

(6) Buchner Funnel - an approved Buchner Funnel.

(7) Vacuum Filtering Flask - 500 ml.

(8) Filter Paper - A hard, fine, retentive filter paper. Whatman #42 or equivalent.

(9) Asbestos Fiber.

(10) Oven - a standard air oven capable of maintaining 130°C (266°F)

(11) Desiccator - an approved desiccator.

SAMPLE PREPARATION:

(1) Air dry the soil sample and weigh out 1.000 gram of the material that passes the No. 10 (2.00 mm) sieve after screening.

(2) Place the 1.000 gram sample in a 400 ml beaker and add 250 ml distilled or demineralized water, cover with an appropriate size watchglass, and bring to a boil.

(3) Remove from heat and stir thoroughly.

(4) Allow sample to remain undisturbed overnight (16-18 hours).

PROCEDURE:

(1) Decant the water from the sample through the Buchner funnel and filtering flask with vacuum applied. The Buchner funnel should be fitted with 2 filter papers plus a thin mat of water soaked asbestos fiber.

(2) Wash filter system after water has been filtered through (the same filter may be used for several samples).

(3) Transfer the filtrate to a 400 ml beaker and place on hot plate uncovered. Evaporate the water until about 50 ml remains.

(4) Transer the water to a 250 ml beaker and continue evaporation to about 10 ml (more if salt content is expected to be high).

(5) Dry to a constant weight in a standard air oven at 130°C (266°F).

(6) Weigh the residue and test for chlorides and sulfates.

Note: If the residue is less than 10 mg (1% of the sample) and there are no chlorides or sulfates present; assume that all soluble salts have been removed. Otherwise continue the Leaching process by adding 250 ml of water and letting stand undisturbed overnight. Start again with procedural step No. 1 until all soluble salts are removed.

CALCULATIONS:

(1) Add the residue weights from each Leaching to obtain the total residue weight.

(2) Calculate the percent soluble salts in the sample as follows:

$$S_s = \frac{(\text{Wt. beaker + salts}) - (\text{Wt. beaker})}{\text{Sample Wt.}} \times 100$$

where $S_s$ = percent soluble salts in the sample

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Utah Department of Transportation, Implementation Packages:

UDOT-IMP-76-1

J. Leatham and G. Peterson, Pipe Selection for Corrosion Resistance, Utah Department of Transportation, Research and Development Unit, 1976.

UDOT-IMP-76-2

G. Peterson and J. Leatham, Commuter Carpool Parking Facilities, Utah Department of Transportation, Research and Development Unit, 1976.